USER'S GUIDE

For Indiana's 2005 Statewide Orthophotography Project

User's Guide Developed by:

Dewberry

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Orthophotography Data Acquisition provided by:

EarthData International (prime vendor)
Woolpert, Inc.

Quality Assurance, Quality Control and Deliverables provided by:

Dewberry and Davis (prime vendor)
Pinnacle Mapping Technologies, Inc.
Major Engineering

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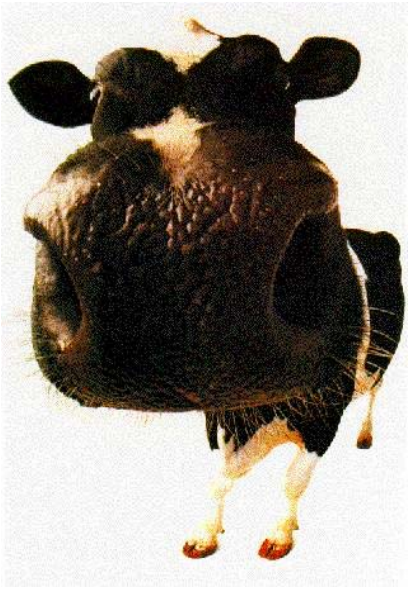
Introduction to Orthophotography

Aerial photography is commonplace in government agencies all across the United States (and beyond). Aerial photographs are among the most important, widely available, and commonly utilized kinds of remotely sensed images.

Aerial photography records the ever-changing cultural and natural features on the Earth's surface. Aerial photos capture residential and industrial areas, road and rail networks, and geographical features including mountains, canyons, flatlands, rivers, lakes, forests, and cropland. Aerial photography has many practical applications such as map-making, urban and rural planning, environmental impact studies, civil law cases, real estate evaluations, and can even be used as wall art.

Many on-line sources for aerial photography exist for government agencies, the public, as well as private companies. On-line availability varies from searchable map databases, to locality maps, and/or browse images, to web sites with off-line ordering instructions.



By its nature, all photography has some amount of distortion. The process to convert aerial photographs into a geographically accurate map image called digital orthophotography (a.k.a. digital orthos) is a mathematical process of removing distortion in an ordinary photography caused by hills and valleys, the curvature of the earth, or orientation of the aircraft when it took the photo.

The traditional orthophotography production method used digitized film images from cameras combined with digital elevation models. The state-of-the-art now includes digital mapping cameras that use either individual frame-based sensors to capture a digital frame image, or pushbroom sensors which scan the terrain with multiple line sensors. The new digital sensor technologies support the simultaneous collection of panchromatic (Black/White), Red/Green/Blue (RGB color) and Color Infrared (CIR) bands, and the digital elevation models are automatically produced through autocorrelation of each pixel to calculate the terrain surface.

The Indiana Statewide orthophotography program utilizes the state-of-the-art ADS40 orthophotography technology. Below we introduce some of the basics of aerial photography, photogrammetry, and orthophotography. Certainly we cannot cover everything that you may need to know, so we have also included a list of useful web sites and books.

Basics of Photogrammetry

This section presents basic information about the techniques and goals of the science of photogrammetry. Much of the material in this section is summarized from the text "Remote Sensing and Image Interpretation", by T. Lillesand and W. Kiefer, and the reader is referred to this primary source for more detailed information. In addition, entire texts are devoted to the subject, such as "Elements of Photogrammetry" by Wolf.

Photogrammetry can be defined as the science of obtaining reliable measurements and producing maps by means of photography. Photogrammetric techniques are required to

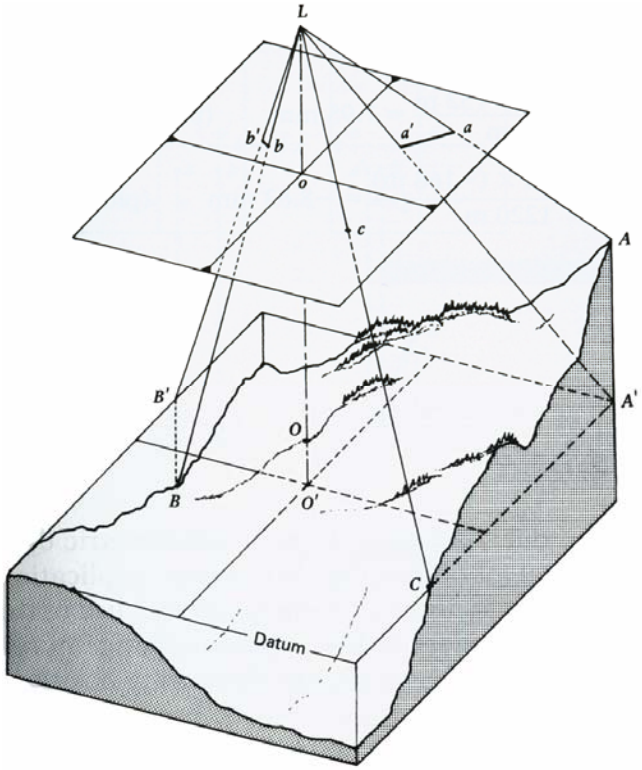
accurately determine relationships of features on aerial photographs, including ground distances and angles, the heights of objects, and terrain elevations.

The principals of modern day photogrammetry have been developing since 1913, when they were used for reconnaissance missions for World War I. Throughout the following decades, architectural and engineering firms began using photogrammetry for site surveys. It wasn't until the 1980's that government agencies realized how photogrammetry could play an active role in managing a City, County or State. That boom of acceptance coincides with the growing applications of GIS (Geographical Information Systems) in those same government agencies.

When an aerial photo is taken, the exact point on the scene that is directly below the center of the camera is called the ground principal point. Lines drawn to connect marks located along opposite sides of the photo (fiducial marks) intersect precisely at the principal point. This relationship, together with the flying height and the camera, form the basic coordinate system used to quantify various elements of the image.

Identifiable points on the ground (ground control points) are used to determine distances and geometric properties of the image, including camera height above the ground, degree of tilt at the time the photo was taken, and distance between photo centers, and to correct for distortions on the image. Distortions that commonly occur on aerial photographs include: relief displacement of vertical features (the top of tall objects appear to lean away from the principal point); and image parallax (the misalignment of the principal point-fiducial axes from image to image based on unavoidable changes in the orientation of the aircraft along its flight axis).

In order to correct (or rectify) these distortions, overlapping photos and ground control points are integrated to produce a stereo model of the terrain, which forms the basis of photogrammetric mapping and orthophotography. Ground control, or accurate geodetic data, is essential for all photogrammetric operations.



Orthophotos are being produced for many parts of the country, and combine the constant scale and accuracy of a map with the detail of an aerial photograph. Modern mapping and orthophotography are just two of the products of the science of photogrammetry.

Basics of Orthophotography

Aerial photographs contain distortion – either caused by relief of the Earth being photographed or because of the orientation of the aircraft taking the photo. The process of creating a digital orthophoto involves a couple of steps. The first step is the creation or introduction of a surface model. A surface model is used to define the topography of the Earth's surface over a

given geographic area.

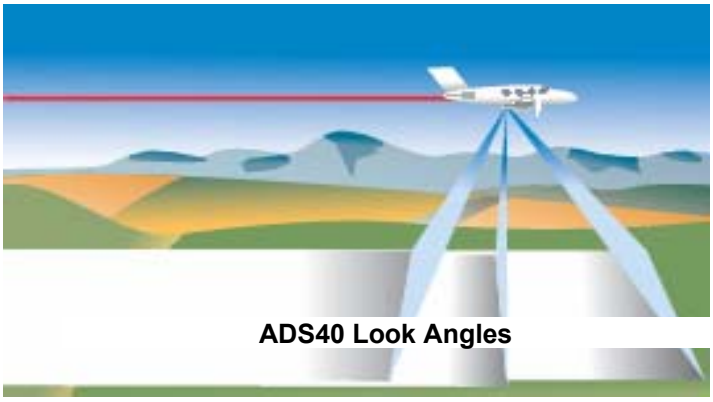
The role of a surface model in the orthorectification process is to correct for relief displacement in the photography. The above image (taken from the 5th Edition of Remote Sensing and Image Interpretation by Thomas Lillesand, Ralph Kiefer and Jonathan Chipman) illustrates the relief displacement principle.

Orthophotos are digital images that are produced by making geometric corrections to digital aerial photographs. The distortion in aerial photographs is removed by unwarping the effects of terrain, removing the perspective projection of the camera, and by fitting the image to a particular map projection to create an "image map" that has a uniform scale and a known accuracy. Hence, orhtophotographs can be used as a map whereas aerial photographs cannot. In computer systems, they can be integrated with other geographic information providing a rich visual context.

Due to their properties, orthophotos are more readily used for measurement and spatial analyses because they do maintain a constant scale across the image.

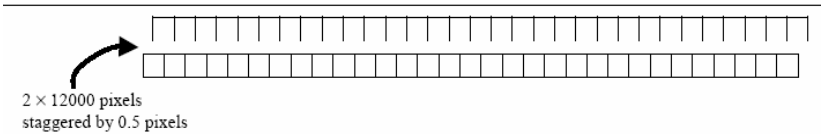
Basics of ADS40 Imagery

As shown in the figure on the right, the ADS40 is a "push-broom" sensor with linear arrays that look forward, downward, and backward and collects up to 800 lines per second, each line being 12,000 pixels wide. The most commonly used stereo view is from the forward and downward lines, where the stereo angle is 26 degrees. The downward to backward stereo angle is 16 degrees, and the forward to backward stereo angle is 42 degrees. Any of these combinations can be used to create stereo views.



ADS40 Look Angles

Panchromatic Dual Staggered Arrays

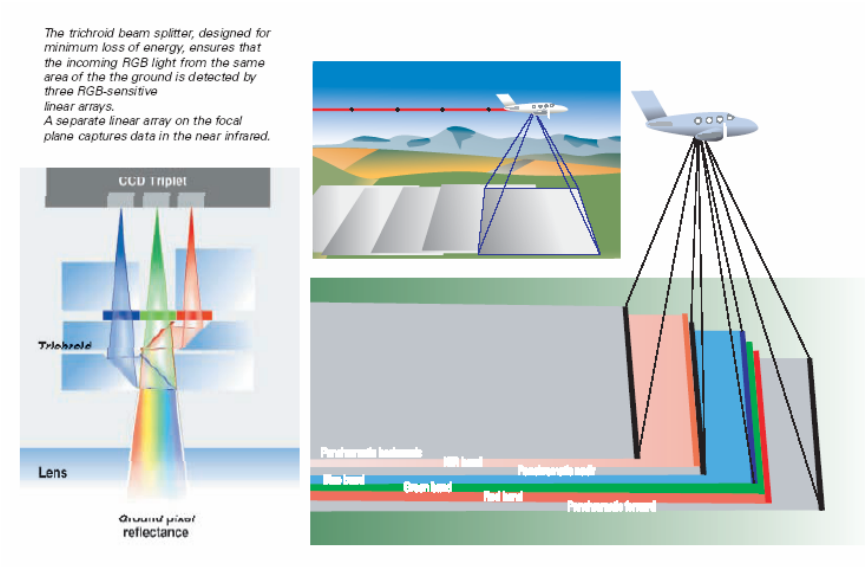


The panchromatic scan lines (465 – 680 nm) are actually two lines, each having 12,000 pixels, where one line is offset by a half pixel to improve image sharpness.

The three color scan lines are actually three (Red Green Blue (RGB)) lines, each having 12,000 pixels, known as the blue sensor (430 – 490 nm), green sensor (535 – 585 nm), and red sensor (610 – 660 nm). The trichoid beam splitter (see the figure below), designed for minimum loss of energy, ensures that the incoming RGB light from the same area of the ground is detected by the three RGB sensors; this is called "telecentricity." One or more separate linear arrays on the focal plane capture data in the near infrared (NIR). Different

ADS40 cameras have been built for diverse clients with different wavelengths, e.g., NIR1 (703 – 757 nm) and NIR2 (833-887 nm)

The panchromatic scan lines, three RGB lines, and one or more NIR lines, each produce long, continuous strips of *Level 0* imagery that is distorted by the *orientation*, i.e., roll, pitch, and yaw (ω/φ/κ) of the aircraft in flight. The field of view is up to 64 degrees cross-track. The swath width at 3000m altitude is 3.75 km, with ground sample distance of 30 cm (11.8").



Trichoid Beam Splitter

Orthophotos in Indiana

Indiana took a bold step forward with the 2005 Statewide Digital Orthophotography project. This project created high-resolution digital orthophotography for counties on a statewide basis to support homeland security, emergency management, and multi-use government applications. The orthophotography project provides a current, accurate, statewide, seamless base map at significantly reduced costs over county-by-county data collection.

Project Deliverables

Digital Orthophotography and Viewers

After performing completeness checks and formally accepting all the data for a county by the quality assurance vendor Dewberry, Pinnacle Mapping delivered the statewide data set on firewire drive from EarthData to the State and delivered the final data sets on DVD/CD-ROM media to each appropriate county. The CD-ROM's are single sided with a data capacity of 700 MB. The DVD's are single sided with a data capacity of 4.7 GB (4.3 usable), although each disk delivered may not be completely filled with data.

All of the digital orthophotography required to cover a county with a minimum 4000' buffer inside state boundaries and a 1000' buffer outside state boundaries (or opposite bank of the river if greater than 1000') have been delivered to each county in the state of Indiana. The digital orthophotography is seamless within a county and across the state. Orthophotography is produced at one of two resolutions based on county options.

There were four sets of deliverables with the project, each described below:

Deliverable 1 – Base Product

Each county shall receive the following on DVD as its deliverable:

1. County set of applicable 1-foot or 6-inch resolution orthophotography uncompressed TIFF files, a clearly marked "Public Version" if applicable. The state is a recipient of all deliverables as specified in the state contract with EarthData.
2. MrSID Compressed Tiles for all 4000' x 4000' tiles will be created. The compression ratio is 20:1.

An additional disk with each county includes a data installer with the following functionality:

1. Launch installer – As the application loads, splash screen displays project logos. The splash screens fade out and the main installation menu displays.
2. Main Installation Menu – Displays the County Name and Product Name. Two options are provided – Install or Exit. Product instructions are then displayed, and the user then decides if he/she wants to continue with the installation.
3. A default installation drive (C:\) is displayed, but the user can alter the target drive to load the data elsewhere on his/her system.
4. Installation will begin and the only user interaction will be to load the next DVD when prompted by the application.

Deliverable 2a – MrSID Products (State Plane)

A high-resolution compressed imagery mosaic was created to provide seamless contiguous coverage for each political township in a county (plus 1000' overlap) in a single file. Each township mosaic file has a 50:1 compression. LizardTech's MrSID Generation 3 imagery compression and mosaic technologies were used to create this product. Each county delivery included the following three (3) product sets using the Indiana State Plane Coordinate System:

1. TWP. Mosaic files delivered to the state on DVD
2. TWP. DVD ISO files will be delivered to the state on firewire drive
3. TWP. Mosaic files delivered to each county on DVD

Deliverable 2b – MrSID Products (Lat-Long)

A high-resolution compressed imagery mosaic was created to provide seamless contiguous coverage for each political township in a county (plus 1000' overlap) in a single file. Each township mosaic file has a 50:1 compression. LizardTech's MrSID Generation 3 imagery compression and mosaic technologies were used to create this product. Each county delivery included the following three (3) product sets using Lat-Long (for E-911 applications, and software that does not support on-the-fly re-projection of imagery):

1. TWP. Mosaic files delivered to the state on DVD
2. TWP. DVD ISO files will be delivered to the state on firewire drive
3. TWP. Mosaic files delivered to each county on DVD

Deliverable 2c – Color Infrared and Elevation Products

A color infrared (CIR) data set was produced statewide at 1-meter resolution. A digital surface model (DSM) and digital elevation model (DEM) were also produced. Each county delivery includes the following products covering the area of their respective county:

1. CIR 1-meter resolution imagery TIFF files in UTM projection
2. DSM delivered in 4000'x4000' tiles that correspond to the original orthophotography tiles, in .IMG file format
3. DEM delivered in 4000'x4000' tiles that correspond to the original orthophotography tiles, in .IMG file format

Deliverable 3 – IndianaMap Viewing Application

An IndianaMap Viewing Application has been developed that provides additional data and the ability to use the data with free GIS software. The application uses the free AccuGlobe 2004 GIS viewing software developed by DDTI. The AccuGlobe GIS software can be downloaded from the DDTI web site at www.ddti.net. Pinnacle Mapping Technologies customized AccuGlobe project files (e.g. Marion_Co_IndianaMap_Viewer.epf & Marion_Co_IndianaMap_Viewer.xml) for each Indiana county. The county IndianaMap Viewing Application is delivered on 3-4 DVD's per county, and include over seventy-five additional (vector) map data layers.

The MrSID township imagery (created with Deliverable 2a) is also included. Each county delivery will include the following three (3) product sets:

1. 5 copies of DVD set to each county
2. 5 copies of DVD set for each county to state
3. 1 copy of ISO master on firewire drive to state for additional duplication

Deliverable 4 – Indiana First Response Map (INFRM) Application

An Indiana First Response Map Application (for first responders / for official use only) was developed to be shared within the emergency management community for users who don't already have GIS capabilities. ArcReader is a free viewer of GIS data from ESRI. The application is built in Windows.NET development environment in C# and has been customized by Pinnacle Mapping Technologies. ArcReader Published Map Files (.PMF) were created for use in the FirstView-First Responder emergency management application. The application is provided per county with the 50:1 compressed township mosaics (Lat/Long coordinate system).

The Indiana First Response application will allow County Emergency Management personnel to expand their access and use of the new high-resolution imagery by integrating it with the state's emergency management layers which are included on the disks. All the additional data are in ESRI "shapefile" format can be used with other compatible GIS software. Each county delivery will include the following:

1. 5 copies of DVD set to each county
2. 5 copies of DVD set for each county to state
3. 1 copy of ISO master firewire drive to state for additional duplication

The INFRM product (as packaged and delivered) is not openly available to the public, but the INRFM viewing application (without the data) is FREEWARE and is available to the public.

Summary of Deliverables

Each county will receive several sets of disks; the following is a list of all the data:

Public Products:

- 4000'x4000' uncompressed TIFF tiles in Indiana State Plane Projection (6-inch or 1-foot)
- 4000'x4000' MrSID tiles in Indiana State Plane Projection (6-inch or 1-foot)
- Township MrSID Mosaics in Lat-Long Projection (6-inch or 1-foot)
- Township MrSID Mosaics in Indiana State Plane Projection (6-inch or 1-foot)
- 1-meter RGB Digital Ortho Quarter Quad (DOQQ) uncompressed TIFF tiles in UTM Projection
- 1-meter RGB Digital Ortho Quarter Quad (DOQQ) MrSID tiles in UTM Projection
- 1-meter Color-Infrared Digital Ortho Quarter Quad (DOQQ) TIFF tiles in UTM Projection
- 5-foot Digital Elevation Model IMG tiles in State Plane Projection
- 5-foot Digital Surface Model IMG tiles in State Plane Projection

Applications

- IndianaMap Viewing Application
- Indiana First Response Map Application

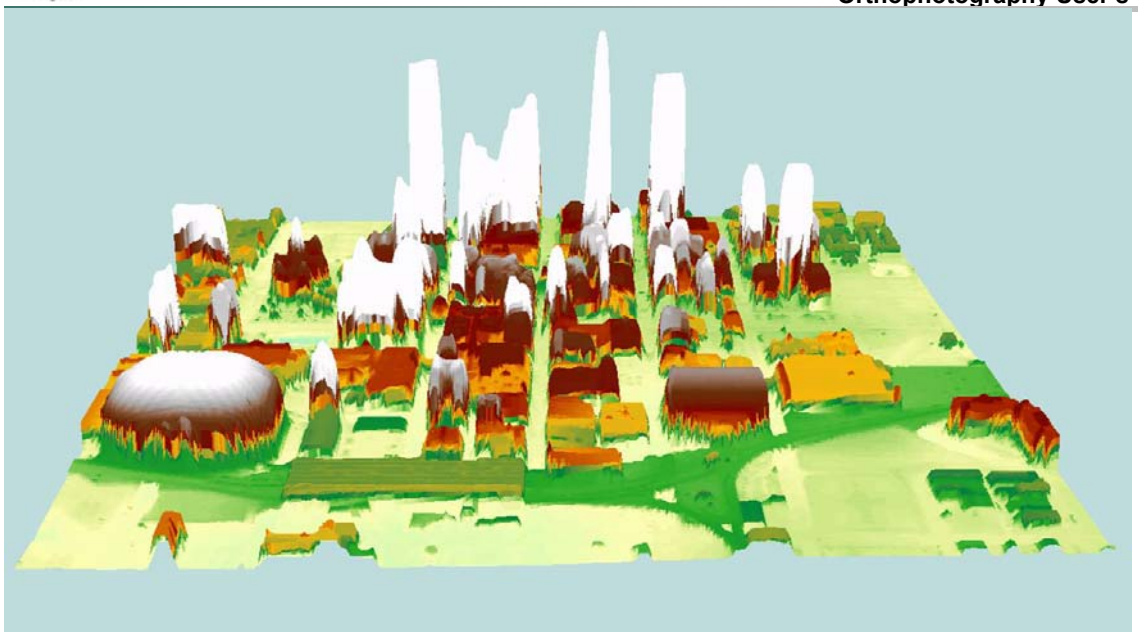
For Official Use Only (FOUO) Products (select counties):

- 4000'x4000' uncompressed TIFF tiles in Indiana State Plane Projection (6-inch or 1-foot)
- 4000'x4000' MrSID tiles in Indiana State Plane Projection (6-inch or 1-foot)

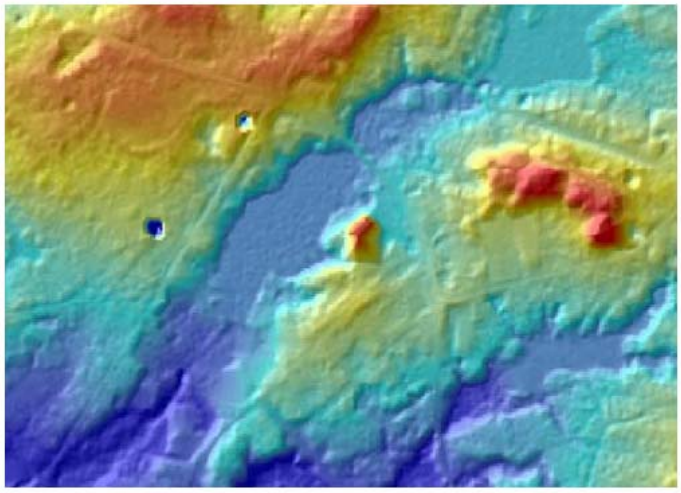
Digital Surface Model (DSM)

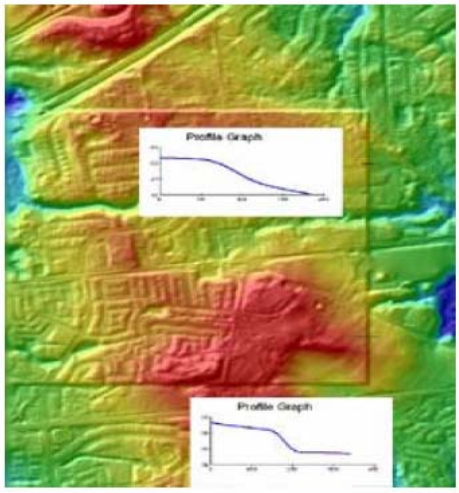
The Digital Surface Model (DSM) represents the top reflective land surface determined by ISTAR auto-correlation of ADS-40 stereo images. The DSM is used in the ortho-rectification process for the digital orthophotos, and DSMs need only be accurate enough for orthophoto production.

The DSM is generated through a method known as auto-correlation. This technique involves using complex image matching algorithms to calculate the height displacement in the image and so compute the height of every pixel. This produces a "first return" surface that includes surface features such as buildings and trees.



There may be minor anomalies in the DSM that were not corrected as part of this project (the DSM and DEM are corrected to meet the specifications of ortho-rectification). For example, when there are long stretches of asphalt highway running parallel to the direction of the airplane flight, the image correlators can get confused by the similar texture and appearance. The same problem can occur with large water bodies, plowed fields, or areas of sand or dark shadows. This can cause the DSM to be distorted which, in turn, will cause waviness in roads and buildings on the digital orthophotos. When correlators get confused, artificial "sinkholes" or "spikes" can form in the DSM. If these artifacts are near the nadir of the flight line, they normally have minimal impact on the horizontal position of imaged features. However, when DSM artifacts form towards the outer edge of an ADS40 flight line, this may cause significant distortions and waviness to imaged features such as roads and buildings. These distortions are typically removed through additional processing and all Indiana DSM's have been reviewed for these artifacts.





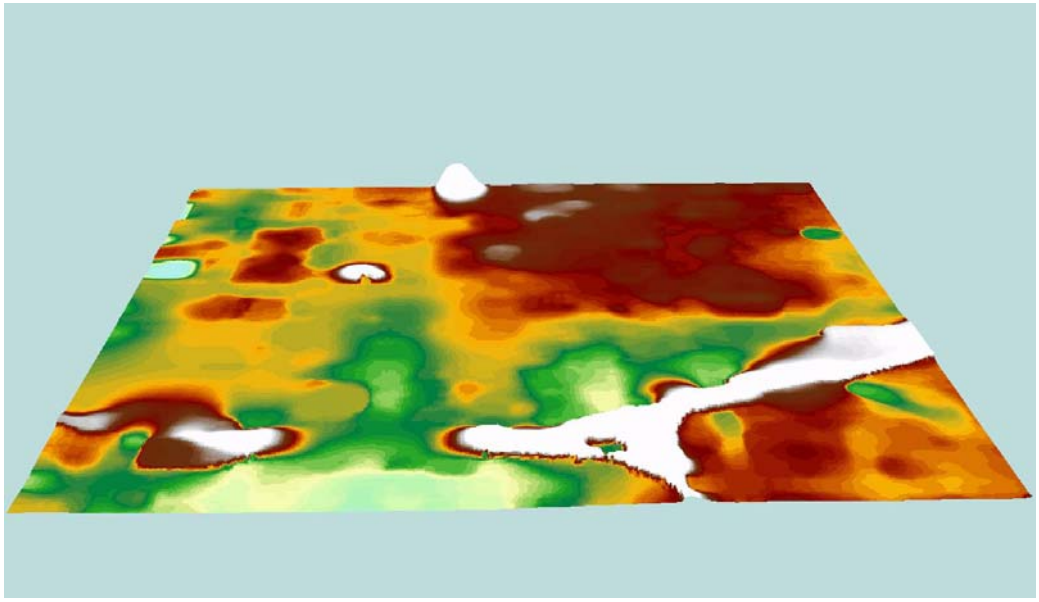
The quality assurance review process for the DSM models is built around an ESRI environment. This platform allows us to build a custom elevation tool set through Model

Builder, 3D Analyst and Spatial Analyst to streamline product generation and to focus energy on the analysis where it is needed most. DSMs need only be accurate enough for orthophoto production.

Using the elevation tool set, we are able to create pseudo 3D visualizations of the different terrain types, and coupled with a statistical analysis, we are able to quickly identify anomalies in the data. Since the source data is an ERDAS Imagine file, a direct plug-in for ArcMap enables us to utilize the data with no conversion at all and is easily incorporated directly into our process flow. To create our 3D pseudo visualizations programmatically, our elevation tool set reads in the data, converts it to a hillshade, combines the grid elevation model and then symbolizes the data with the correct symbology to best identify anomalies. By utilizing a blue to red scheme we can quickly identify high and low points, and elevations that do not fit the norm. The above figures illustrate this technique. The second figure illustrates an edge join issue where one tile is higher than the surrounding tiles (this error was later corrected). Additionally, a histogram may be produced and the statistics reviewed if deemed warranted by the QC analyst. For each DSM tile, Dewberry reviewed the elevation models for completeness of coverage, and to check the model for blunders in a 3D software environment as described to determine suitability for ortho-rectification.

Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) is normally presumed to be the same as a bare-earth surface model from which surface features, such as buildings and trees, have been removed from the DSM. The points are filtered to a DEM "near bare earth" surface through a point classification and filtering algorithm.



The DEM products have been certified to support creation of 10-foot contours or equivalent digital elevation models with no further processing. The quality assurance statements provided with the DEMs reads as follows:

"It is recommended that additional ground control points be collected and the AT re-processed before utilizing any given data for generation of elevation data of higher accuracy than 10-foot contours or equivalent digital elevation models (DEMs)."

Deliverable Review & Acceptance Criteria

All products from the Indiana 2005 Orthophotography Project underwent rigorous quality assurance and quality control (QA/QC) procedures. The following documents the review and acceptance criteria:

	Tested Characteristic	Measure of Acceptability
	All Scales (100-Scale, 200-Scale, 1,000-Scale)	
1.	Media: DVD 2.0, 4.7 GB single sided (4.3 GB usable)	Media is readable, all files accessible, no files corrupted
2.	Media label	As specified by IDHS
3.	File organization	Pinnacle's files written in tile sheet order
4.	File name	Conforms to required convention
5.	TIFF with World file (.tfw) format	File reads in ESRI and Intergraph
6.	Files must open in correct location with standard software	Files must open with ArcGIS, then usable also with MicroStation and AutoCAD
7.	Pixel definition	World file must reference the center of the pixel located in the upper left hand corner of the tile as the point of origin.
8.	Georeferencing	World file has correct coordinates expressed to at least 2 significant digits, and correct pixel size
9.	MrSID mosaics	Correct compression ratio, 20:1, reads in ArcGIS
10.	Projection	6-inch/1-foot TIFFs: • Indiana East State Plane – 1301 (tile respective zone) • Indiana West State Plane- 1302 (tile respective zone) 1-meter GSD color and CIR quarter-quads: • UTM Zone 16 North
11.	Datum	NAD 83 (1986 adjustment) reference datum
12.	Units	U.S. Survey Feet (meters for UTM products)
13.	24 bit natural color	256 levels of value for each band, 0=black, 255=white
14.	Tonal quality	< 2 percent of values at 0 or 255, to the extent possible per client's radiometry choices
15.	Image blemishes, scratches, and artifacts (Note: these generally pertain to film imagery rather than digital imagery)	Generally acceptable within these limits: If 1 pixel wide, 100 pixels in length. If 2 pixels wide, 60 pixels in length. If 3 pixels wide, 20 pixels in length. If 4 - 12 pixels wide, 12 pixels in length. Artifacts exceeding these limits may be acceptable if ground feature detail is not obscured, or if the brightness value of the pixels in the artifact is under 170. Artifacts within these limits may be rejected if critical ground features are significantly impacted. Critical features shall be defined as features having County, State or National significance (i.e. Courthouses, Capitol Buildings, etc.). Clusters of artifacts that do not individually meet these criteria may be considered unacceptable if more than 12 are visible within a viewing screen at 1:1 zoom.
15 a	ADS40 sensor anomalies	The following artifacts are created occasionally by the sensor and cannot be avoided currently:

		• Image duplication/ghosting/echos • Optical/spectral reflection • Look angle
15 b	Registration between natural color and CIR ortho sets	Due to different look angles from RGB and CIR cameras, some elevated objects such as bridges may look slightly shifted when they are compared to each other
16.	Conformance of sheet to index grid	Sheet matches grid, no gaps between tiles at 1:1 view.
17.	Image Appearance	The difference in average pixel values on either side of a mosaic seam-line should generally not exceed 70 (30 preferred), when measured on a homogeneous surface with similar characteristics (water surfaces are exempt from this requirement). Greater differences may be allowed if the correction will cause significant degradation of the image content on either side. No image will be rejected for such radiometry inconsistencies without prior approval of IDHS.
18.	Smears	Normally corrected by adding mass points or breaklines to DEM/DSM as necessary to reflect actual terrain or by image processing where appropriate. Where DSM/DEM corrections or image processing will result in reduced horizontal accuracy or misrepresentation of the location or appearance of important features (buildings, roads, etc.), the smear will remain untreated. No image will be rejected for smears without prior approval of IDHS.
19.	Wavy features	Distinct linear ground features (such as road markings, and curbs) should not deviate from their apparent path by more than 5 pixels measured perpendicular to the feature within any 100 pixel distance measured along the feature length.
20.	Mosaic lines	No mosaic lines through buildings. No mosaic lines through above ground transportation structures carrying automobiles or trains unless unavoidable.
21.	Metadata	Complies with standard (to be determined by IDHS). Meets minimum FGDC Content Standard or Indiana Tier 2 Metadata Content Standard
22.	Building lean	No rigid criterion; but Dewberry is to question if traffic lanes, striping or sidewalks are obscured.
	1-meter GSD, equivalent to 1"=1,000'-scale (1,000-Scale)	
23.	Ground Resolution	1 meter
24.	Sheet size	Quarter-quad (3.75 x 3.75 arc minutes)
25.	RMSE of QA/QC points measured on the image *See ASPRS Class I Standards Page 8, Table 16, and NSSDA Part 3, Appendices 3-A and 3-D for explanation of formulas.*	$RMSE_x = RMSE_y$ = 2.04-meters (6.69-ft) or $RMSE_{r=}$ = 1.4142*$RMSE_x$ = 2.89-meters (9.48-ft)
26.	Absolute accuracy	NSSDA accuracy (95% confidence level) such that 1.7308 * $RMSE_r$ < 5 meters (16.4-ft)
27.	Mismatch of features along mosaic	Equal to or less than 3 pixels (3-meters) on well

	lines and production block boundaries of equal scale	defined ground features (roads, sidewalks, curbs).
	1-foot GSD, equivalent to 1"=200'-scale (200-Scale)	
28.	Ground Resolution	1.0 US Survey Feet
29.	Sheet size	4,000' (4,000 pixels) E-W by 4,000' (4,000 pixels) N-S
30.	RMSE of known ground points measured on the image *See ASPRS Class I Standards Page 8, Table 16, and NSSDA Part 3, Appendices 3-A and 3-D for explanation of formulas.*	$RMSE_x = RMSE_y = 2.04$-ft or $RMSE_r = 1.4142*RMSE_x = 1.4142*RMSE_y = 2.89$-ft
31.	Absolute accuracy	NSSDA accuracy (95% confidence level) such that $1.7308 * RMSE_r < 5.0$-ft
32.	Mismatch of features along mosaic lines and production block boundaries of equal scale	Equal to or less than 3 pixels (3-ft) on well defined ground features (roads, sidewalks, curbs).
33.	Mismatch of features between 1-foot and 6-inch images (only if IDHS wants this to be QC'ed)	Equal to or less than 3 feet on well defined ground features (roads, sidewalks, curbs). 4 foot maximum on all measurable features.
	6-inch GSD, equivalent to 1"=100'-scale (100-Scale)	
34.	Ground resolution	0.5 US Survey Feet
35.	Sheet size	4,000' (8,000 pixels) E-W by 4,000' (8,000 pixels) N-S
36.	RMSE of known ground points measured on the image *See ASPRS Class I Standards Page 8, Table 16, and NSSDA Part 3, Appendices 3-A and 3-D for explanation of formulas.*	$RMSE_x = RMSE_y = 1.02$-ft or $RMSE_r = 1.4142*RMSE_x = 1.4142*RMSE_y = 1.44$-ft
37.	Absolute accuracy	NSSDA accuracy (95% confidence level) such that $1.7308 * RMSE_r < 2.5$-ft
38.	Mismatch of features along mosaic lines and production block boundaries of equal scale	Equal to or less than 3 pixels on well defined ground features (roads, sidewalks, curbs).

Aerotriangulation Acceptance Criteria

	Tested Characteristic All Scales	**Measure of Acceptability**
39.	Report Format	Conforms to required convention
40.	Report Completeness	All information complete and readable
41.	Precision of Image Observations	Sigma (0) less than or equal to 5 microns is acceptable. Over 5 microns is subject to review.
42.	AT Horizontal accuracy against ground control	RMSE values are acceptable up to 1/10,000 the flying height AMT or 0.47', 0.95' and 3.2' for the 6", 1' and 1-meter AT blocks respectively in the x and y directions. Higher RMSE values are subject to review.
43.	AT Vertical accuracy against ground control. EarthData to provide flying	RMSE values are acceptable up to 1/10,000 the flying height AMT or 0.47', 0.95' and 3.2' for the 6",

	heights above mean terrain for each lift for which an AT report is submitted for evaluation.	1' and 1-meter AT blocks respectively in the z direction. Higher RMSE values are subject to review.
44.	NSSDA analysis [E, N] at 95% confidence level	95% within 1.73 * RMSE for that scale

Ground Control Acceptance Criteria

	Tested Characteristic All Scales	Measure of Acceptability
45.	Report Format	Conforms to required convention
46.	Report Completeness	All information complete and readable
47.	Geodetic survey: Horizontal accuracy against HARN control	Standard deviation to existing control within 5-7 cm. Pertains to control surveys by Woolpert.
48.	Geodetic survey: Vertical accuracy against HARN control	Standard deviation to existing control within 5-9 cm. Pertains to control surveys by Woolpert.
49.	Ortho Accuracy: NSSDA analysis [E, N] of blind QA points	95% within 1.73 * $RMSE_r$ or 2.447 * $RMSE_x$ for that scale

Digital Surface Model / Digital Elevation Model QA Acceptance Criteria

	Tested Characteristic All Scales	Measure of Acceptability
50.	Media DVD 2.0, 4.7 GB single sided (4.3 GB usable)	Media is readable, all files accessible, no files corrupted
51.	File organization	Files written one per 4000' x 4000' ortho tile delivered
52.	File name	Conforms to required convention
53.	Format	ERDAS .IMG format
54.	Georeferencing	Locates in proper tile grid cell
55.	Mass point and breakline locations	Mass points sufficient to accurately build terrain to support orthophotos; no breaklines unless needed to control bridges and other elevated features
56.	Mass point locations	Tops, bottoms, and supplementing breaklines as needed for orthorectification, none in open water. Water bodies will not be level; no such requirement for EarthData
57.	Continuity	No spikes, holes or blunders; no gaps of sufficient size to affect orthorectification, regardless of perspective center.

QA/QC Point Acceptance Criteria

	Tested Characteristic All Scales	Measure of Acceptability
58.	Visibility on digital imagery	Well Defined points, QA/QC Defined Points, and Confirmation Points must be clearly photo-identifiable on images at scales evaluated (6-inch and 1-foot)
59.	Well defined	Points must be clearly visible and not elevated (no fence posts, fire hydrants, etc.) that cast shadows
60.	Documentation	Each point is documented to describe the photo-identifiable feature surveyed
61.	Terrestrial images	Each point is photographed from the ground to help in photo-identification
62.	Survey accuracy and description of survey procedure used	Accuracy estimate, to include description of survey procedures used to achieve such accuracy

Operating Options

Hardware

System requirements for use of the 2005 Statewide Orthophotography data will generally be the same as required by the software used to view or access the data.

All data for each county deliverable are provided on DVD's. The data can be loaded on hard disk or accessed from the DVD using a DVD+R reader. Any CD-ROM's are single sided with a data capacity of 700 MB. The DVD's are single sided with a data capacity of 4.7 GB (4.3 usable), although each disk delivered may not be completely filled with data. The orthophotography files are large and the amounts of time required to access or copy these files from the media depends on the speed of the CD/DVD reader, the faster the reader the better. All data for each county deliverable are also provided on hard drive's to the state.

Additional hard disk space (internal or external hard drive) may be required to store or back-up the 2005 Statewide Orthophotography data. This will depend on the capacity of the system on which the data is being loaded and user preferences. External hard disks, which use one of the new fast "firewire" or USB 2.0" connectors may require an adapter card to work with the existing system.

Software

Orthophotography from the 2005 Statewide Orthophotography can be viewed using any software that can read and display the TIFF file format. The TIFF v6 format is widely used and software that supports this file format can generally be grouped into two categories; image viewers and GIS software.

Raster Image Viewing Software

Image viewing software will display raster images like the 2005 Statewide Orthophotography. The images can generally only be viewed one tile at a time. With viewer software images do not have any geo-referencing. Therefore, any measurements made on the photo are reported in photo units rather than in ground units.

"Imaging for Windows" by Kodak which comes by default with the Windows2000 operating system is an example of image viewing software. Additional information on TIFF viewers can be found at http://hazmat.dot.fov/ntsb/ntsb_viewer_help.htm.

CADD/GIS Applications

The orthophotography and DTM data from the 2005 Statewide Orthophotography can be readily opened and used by many CADD (Computer Aided Design and Drafting) and almost all GIS software. One advantage of GIS software is that multiple files can be viewed at one time allowing for the assemblage and viewing of large areas.

These software also use the geo-referencing embedded in the file header or an alternate world file (.tfw) to display orthophotography in its' proper geographic location. TIFF world files are included on the orthoimagery DVD's for software that require separate world files. All locations and measurements on the photo or tile are therefore reported relative to their absolution location on the surface of the earth and measurements are reported in ground units.

Examples of software that can be used to work with the 2005 Statewide Orthophotography data include:

- ILS Geoviewer by International Land Systems Inc. (http://www.landsystems.com)
- ArcExplorer by ESRI, which can be downloaded free from their web site at http://www.esri.com/software/arcexplorer/index.html
- Many other free and commercial GIS software applications exist; for more information on free GIS software, see http://www.in.gov/igic/links/index.html

2005 Statewide Orthophotography Index Files (identifying the tile grid, etc.) are provided in ESRI shapefile format. ArcView, or the free ArcExplorer application and most other GIS software can read the index shapefiles included with the data.

Other 2005 Statewide Orthophotography data included reports (Horizontal Accuracy Reports, AT Reports, etc.), and are provided in Adobe Acrobat (.pdf) file format. Other misc. data tables can be opened and used with a word processing and/or spreadsheet application like Microsoft Word or Microsoft Excel.

Accessing or Loading Data

Loading

The delivered 2005 Statewide Orthophotography data can be used directly from the delivered media, but we strongly recommend installing/copying the desired data to a hard drive.

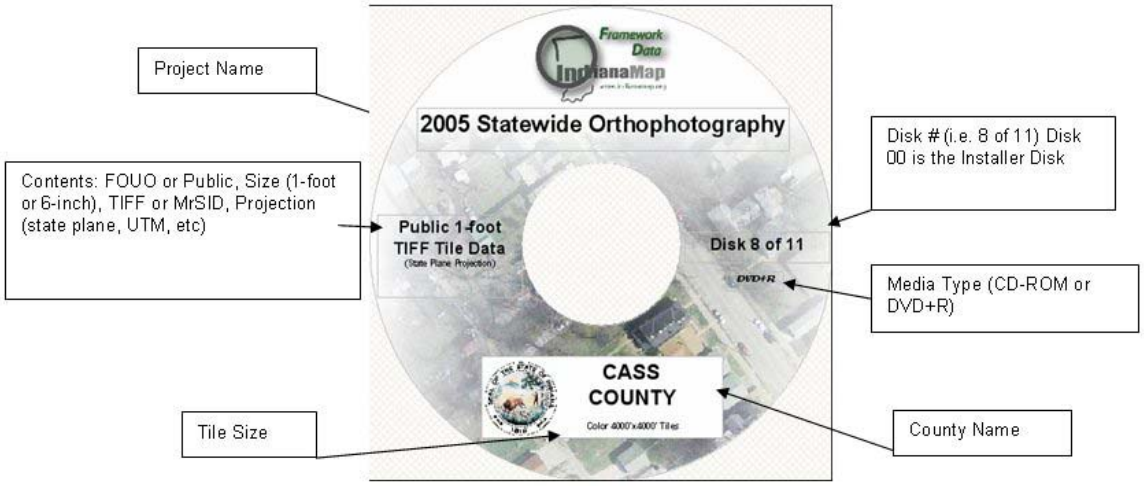
The sub-directory structure of the data on the disk is intended to help organize the data. It is recommended that the directory structure be maintained so that the 2005 Statewide Orthophotography Data Index file will work properly.

Storage

The orthophotography from the 2005 Statewide Project was developed at one of two scales depending on local buy-up options. The imagery is organized by tile with the size of the tile dependant on the scale of the imagery. The size of the file is the same regardless of scale or tile size:

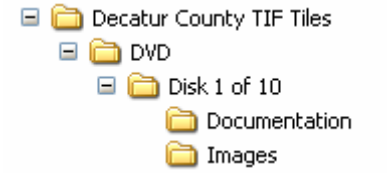
Image Resolution	Imagery Map Scale	Tile Size	Approx. File Size
6 inch (TIFF Tiles)	1" = 100'	4000' x 4000'	183 MB
1 foot (TIFF Tiles)	1" = 200'	4000' x 4000'	46 MB
6 inch (MrSID Tiles)	20:1 compression		9 MB
1 foot (MrSID Tiles)	20:1 compression		2.3 MB

County DVD/CD-ROM'S have the following appearance:

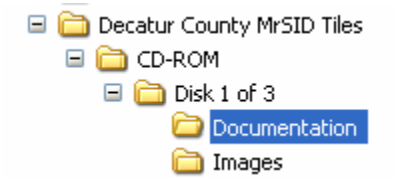


The data structure on each of the installation disks is indicated below along with a brief description of the documentation folder:

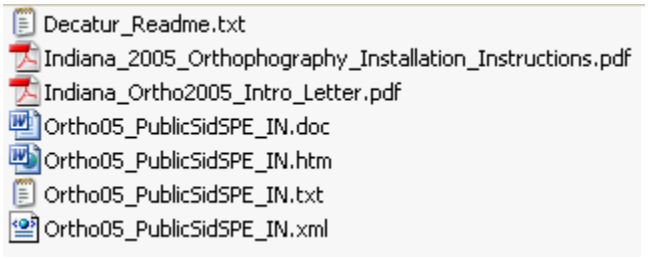
TIFF Data:



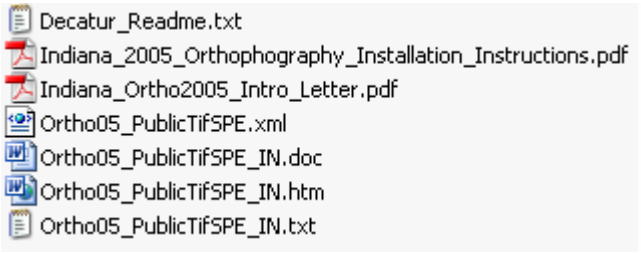
MrSID Data:



The documentation folder in the structure includes the documentation for the corresponding Public or FOUO SID or TIFF tiles in the correct state plane. The files in MrSID documentation are as follows:



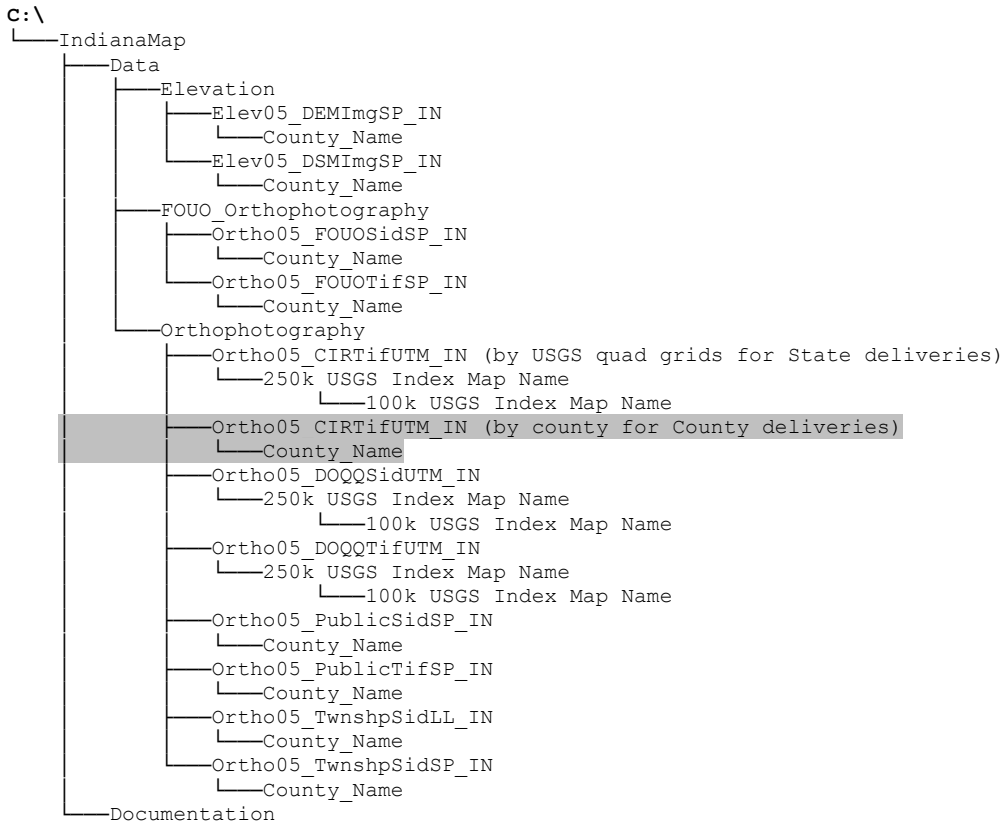
And the files in TIFF documentation folder are as follows:



Data Installation Folder Hierarchy

Part A – 2005 Imagery Products Folder Structure

The following folder hierarchy details only the folder structure for the "2005 Imagery Products". See Part B for the data folder hierarchy of the custom applications.



C:\ is the default root directory for the data installer. This default installation directory and path can be changed by the user as shown in Step 3, but the rest of the folder hierarchy and names cannot be changed during the installation process.

All possible "imagery product" folders are shown in this directory tree structure, but only the folders needed for a specific product installation are created by each custom Indiana Ortho05 product data installer. For example, the uncompressed 1' Pixel TIFF tiles for Sullivan County, IN projected in the State Plane coordinate System will be copied to the following folder:

`C:\IndianaMap\Data\Orthophotography\Ortho05_PublicTifSP_IN\Sullivan\`*`xxxxyyyyL.tif`*

While the 20:1 compressed 1' Pixel MrSID tiles for Sullivan County, IN projected in the State Plane coordinate System will be copied to:

`C:\IndianaMap\Data\Orthophotography\Ortho05_PublicTifSP_IN\Sullivan\`*`xxxxyyyyL.sid`*

Part B – Viewing Applications Folder Structure

The following folder hierarchy details only the parts of the folder structure for data related to the Viewing Application products. See Part A for the complete 2005 imagery products folder hierarchy.

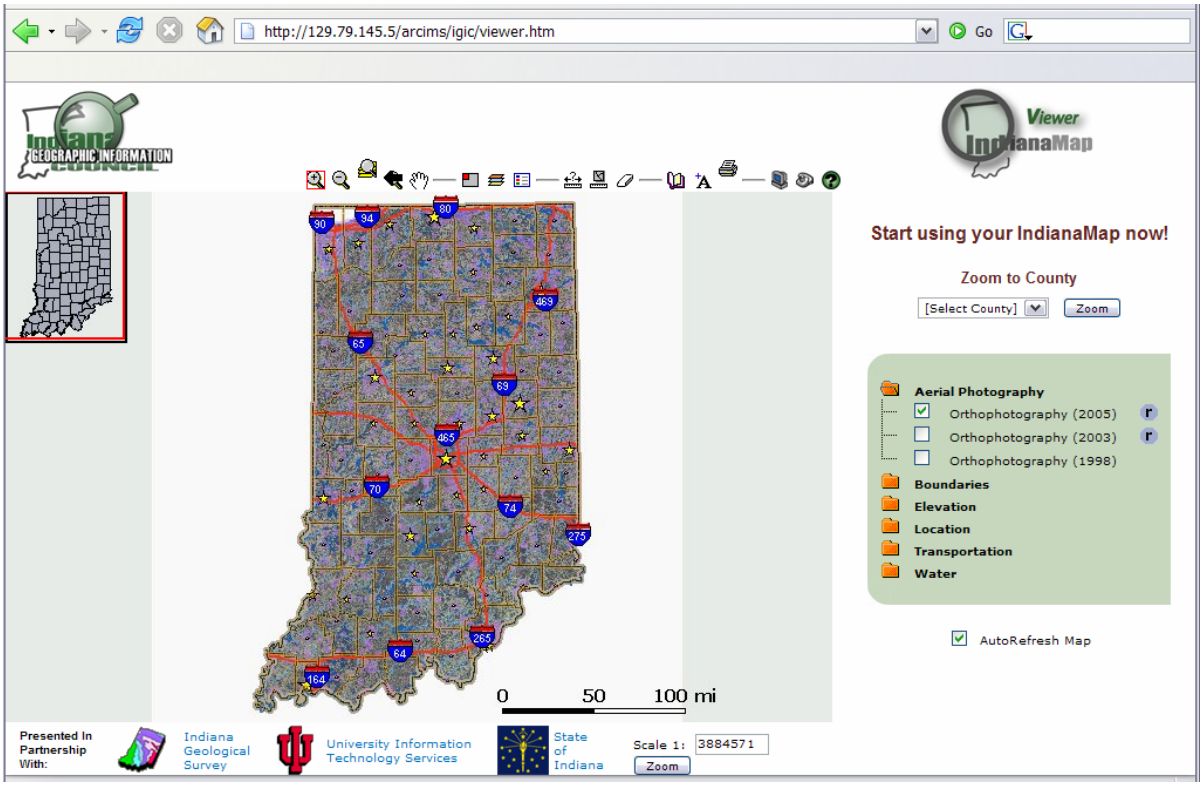
```
C:\
└──IndianaMap
    ├──Applications
    │   ├──AccuGlobe_Installer
    │   ├──ArcReader_Installer
    │   ├──Indiana_First_Response_Map
    │   │   ├──Chemicals
    │   │   ├──Notes
    │   │   └──Projects
    │   └──IndianaMap_Viewer
    ├──Data
    │   ├──FOUO_Indiana_GIS_Data (vector data for the INFRM Application)
    │   │   ├──boita
    │   │   ├──boundaries
    │   │   ├──climatologyMeteorologyAtmoshpere
    │   │   ├──economy
    │   │   ├──elevation (organized by USGS quadrangle map grids)
    │   │   │   └──250k USGS Index Map Name
    │   │   │           └──100k USGS Index Map Name
    │   │   ├──environment
    │   │   ├──farming
    │   │   ├──geoscientificInformation
    │   │   ├──health
    │   │   ├──imageryBaseMapsEarthCover
    │   │   ├──inlandWaters
    │   │   ├──location
    │   │   ├──planningCadastre
    │   │   ├──society
    │   │   ├──structure
    │   │   └──transportation
    │   ├──FOUO_Orthophotography
    │   │   └──Ortho05_FOUOSidSP_IN
    │   │       └──County_Name
    │   └──Orthophotography
    │       ├──Ortho05_TwnshpSidLL_IN (for the INFRM Application)
    │       │   └──County_Name
    │       ├──Ortho05_TwnshpSidSP_IN (for the INFRM Application)
    │       │   └──County_Name
    │       └──Ortho05_TwnshpSidSP_IN (for the IndianaMap Viewing Application)
    │           └──County_Name
    ├──Data_SPE or Data_SPW (State Plane Vector Data for IndianaMap Viewing Appl.)
    │   ├──boita
    │   ├──boundaries
    │   ├──climatologyMeteorologyAtmoshpere
    │   ├──economy
    │   ├──elevation (statewide coverage by north and south half)
    │   ├──environment
    │   ├──farming
    │   ├──geoscientificInformation
    │   ├──health
    │   ├──imageryBaseMapsEarthCover
    │   ├──inlandWaters
    │   ├──location
    │   ├──planningCadastre
    │   ├──society
    │   ├──structure
    │   └──transportation
    └──Documentation
        └──metadata (metadata files for custom viewing application)
```

On-line (Remote) Access

The orthophotography and elevation data are also available via remote access over a high-speed Internet connection. This access is currently provided as a service courtesy of Indiana University UITS and is not intended to be a 24/7 production system.

Viewing

The public can view the 2005 orthophotography via the IndianaMap Viewer www.indianamap.org, hosted in partnership by the Indiana Geological Survey.



Web Map Services

One way for GIS professionals to use the IndianaMap is to load its "Map Services" directly as layers into GIS software that is designed to utilize Web Map Services, such as ESRI desktop GIS software.

The Indiana University-UITS and the Indiana Geological Survey are hosting the orthophotography and IndianaMap Web Map Services (WMS) in partnership with IGIC. The goal is to support Open GIS standards for platform-independent services.

Instructions

These instructions are for use with ESRI ArcMap software. Follow them to create a connection to the map services and use the data in ArcMap.

1. Open ArcMap.
2. Click the Add Data button.
3. In the Add Data dialog box, choose GIS Servers.
4. Double-click Add ArcIMS Server.

5. Enter the URL for the server: http://129.79.145.5
6. Choose framework data services (bulleted below) or the default All services option and click OK.

- Fw_boundaries_govt_units - Includes past, current and future rights and interest in real property, surveys, legal descriptions, parcels, cadastral reference systems e.g. PLSS, and publicly administered parcels e.g. military/state parks/etc.
- Fw_cadastral - Units of government include state, counties, and incorporated places.
- Fw_elevation - Elevations of land surfaces.
- Fw_geodetic_control - Reference system of monumented points and GPS control stations.
- Fw_hydrography - Includes surface water features such as lakes, ponds, rivers, streams, canals, and shorelines.
- Fw_ortho_imagery - Now featuring the NEW 2005 orthophotography, as well as 2003 NAIP orthophotography and 1998 DOQQs
- Fw_transportation - Includes roads, trails, railroads, waterways, and airports; may include street center line and address range information.

7. In the Add Data dialog box, double-click the http://129.79.145.5 connection to view available map services.
8. Select one or more map services and click Add to load the map services into ArcMap.

After you've established the connection the first time, you can add the services to other map projects later by simply repeating steps 3, 7 and 8. Add your own data on top. ArcMap will automatically save the Map Services settings with your .mxd project file.

You can also connect to the orthophotography web map services directly through Indiana University-UITS web map service (just insert the URL in step 5 above):

- http://gis.iu.edu:8290 - Indiana Spatial Data Service at Indiana University

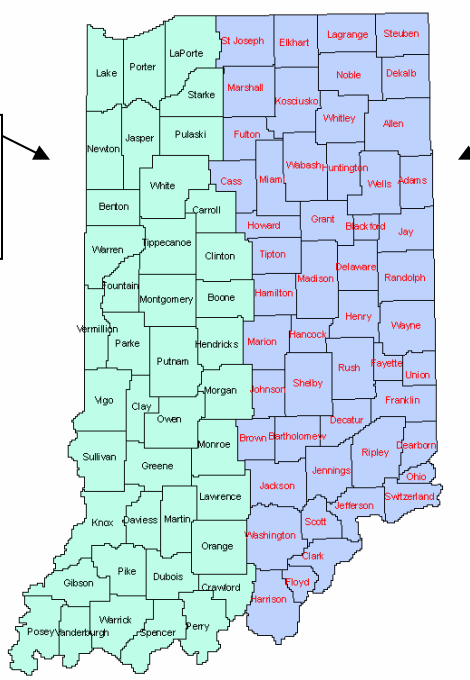
Orthophotography – Tile Grid, Tile Size and Tile ID

Anchoring the Ortho Photos: Tile Grid and Projection

The Indiana 2005 Statewide Orthophotography project has divided the state into "tiles". Each tile represents on aerial photograph. Together the tiles form a grid pattern across the state. The "tile grid" is laid out or anchored in the Indiana State Plane East/West coordinate system. Because Indiana is divided into two State Plane Coordinate Zones, East and West, there are two "tile grids" for the state. One grid is anchored in the Indiana State Plane Coordinate Zone WEST, the other is anchored in the Indiana State Plane Coordinate Zone EAST. Counties and cities that are located at the border of the zones are buffered by an additional 1000 feet in the projected zone into the same zone as the community. The break between the State Plane Projections, East and West runs along county boundaries approximately midway through the state.

Indiana State Plane Zone Index Map

Projected Coordinate System, State Plane, NAD 1983 (feet), Indiana State Plane West Zone (1302)



Projected Coordinate System, State Plane, NAD 1983 (feet), Indiana State Plane East Zone (1301)

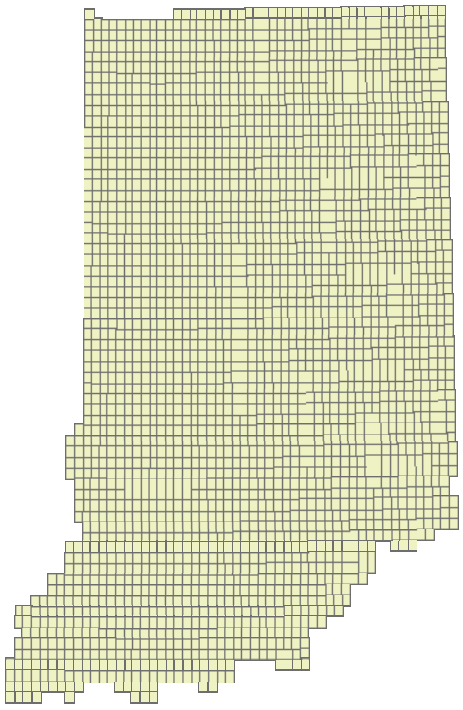
Tile Counts: West Zone & East Zone

32,067 tiles, 4000' x 4000'

34,899 tiles, 4000' x 4000'

Tile Counts: DOQQ's

2,727 Color (RGB) Digital Ortho Quarter Quads
2,736 Color Infrared (CIR) Digital Ortho Quarter Quads

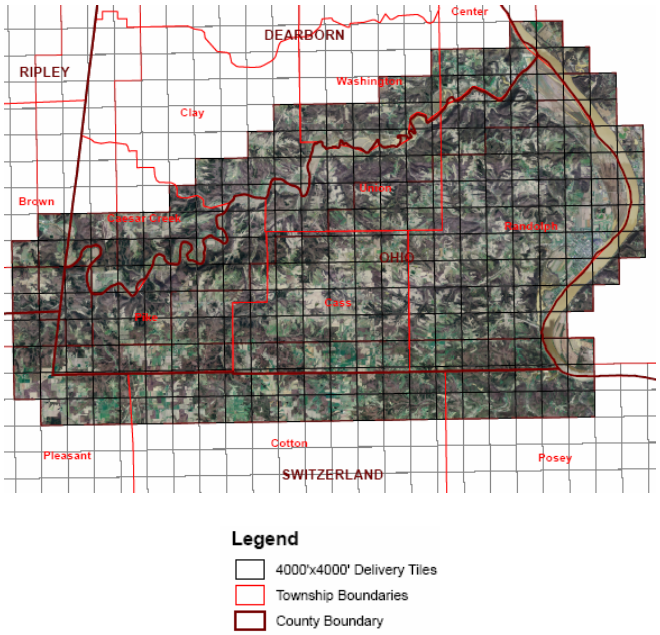


Tile Size based on Scale

In order to provide the best possible orthophotography for each location and meet budget requirements the photography were acquired/developed at two scales based on the county options, either 1 foot or 6 inch resolution. The tile sizes are described below:

- 4,000' x 4,000' TIFF tiles (measured in ground feet) for the 1' resolution – 200 scale photography – 1:2400 scale (1 inch = 200 feet)
- 4,000' x 4,000' TIFF tiles (measured in ground feet) for the ½' resolution – 100 scale photography – 1:1200 scale (1 inch = 100 feet)
- 4,000' x 4,000' MrSID tiles (measured in ground feet) for the 1' resolution compressed at 20:1
- 4,000' x 4,000' MrSID tiles (measured in ground feet) for the ½' resolution compressed at 20:1

Sample County Tile Grid
Ohio County

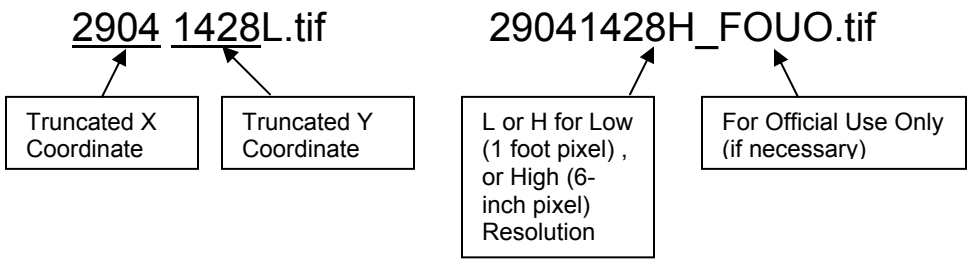


Tile Naming Convention – Tile ID

In order to be able to work with the tiles/photos it was necessary to give each tile a unique identifier or name and to use a logical process for determining ID's/names. Each tile has an 8-digit number assigned to it and is followed by either an "L" or an "H", and in cases for areas that are "For Official Use Only" an "_FOUO" is added to the end. The 8-digit number is based on the lower left corner coordinate of each tile. The digits are the truncated X coordinate in thousands (first 4 digits) tethered with the truncated Y coordinate in thousands (last 4 digits).

Of course there is an exception occurring in the East Zone. Here, there are some tiles where the X value is < 100,000 wherein the X coordinate is truncated in hundreds and multiplied by 10. The 8-digit number is followed by an "L" or an "H". The "L" stands for low resolution which is added to tiles that are 1 foot pixels and the "H" is for high resolution which is added to the tiles that are 6-inch pixels. As stated before, a "_FOUO" may be added to the end of the tile name to indicate that a tile is "For Official Use Only".

Examples:



ISO's

The State of Indiana has been provided with a set of ISO files for each DVD and CD containing digital high-resolution color orthophotography and elevation data for each county in Indiana.

What is an ISO image?

In the context of files and programs, an ISO is simply a file that can be used as a virtually identical copy of the original DVD or CD media. This file not only contains individual data files, but it also contains track and sector information and arranges all this information in a file system, just like disk media. ISO Image files, unlike normal files, are usually not opened; rather, they are mounted.

An ISO image is simply a CD-ROM image saved in ISO-9660 format.

ISO images are mainly used as source files from which to burn additional CD's or DVD's. As an example, most distributions of Linux release ISO images of the installation CD's. These images are usually available from anonymous FTP servers (such as Indiana University's ftp.ussg.iu.edu server). Once you download the ISO image, you can use the CD burning software to recreate the physical CD-ROM install media.

The TIFF data files for each county are delivered on DVD+R digital media while the MrSID data files are delivered on CD-ROM digital media. To allow easy burning of full-county datasets to recordable media, ISO image files of each delivered disk were created and are available on Indiana University's Massive Data Storage System.

Four file format versions of each county's orthophotography are available. TIFF files provide original, uncompressed data. MrSID compressed files and file mosaics result in smaller file sizes, and are generally easier to manage and share.

With the exception of ISOs and data products identified as "For Official Use Only" (FOUO), all data is in the public domain and has no restrictions on distribution. Credit should be listed as "IndianaMap Framework Data" with links to www.indianamap.org. The IndianaMap logo can be used on maps and web sites with the data.

To extract data from an ISO image, complete the following steps:

1. Open a browser to the following location: http://storage.iu.edu/DOQQS/inmap05/nc/cty/
2. Click the folder for the county you want.
3. Click the iso folder to see a list of CD/DVD image files.
4. Click the desired ISO file (note the __00.iso is the Installer disk image, and the __01.iso through __nn.iso are the corresponding data disk (Disk 1 of nn) images for the complete data product.
5. Save the .iso image file to your computer.
6. Navigate to the location of the saved .iso image file and double-click the .iso icon. The CD-writing software you have on your computer, such as Roxio Easy CD Creator, will open automatically. You will see the Record CD Setup window.
7. Insert a blank CD or DVD and record data to disk. Note: Make sure to open the .iso file for burning to media. Do not simply add the .iso file as data to be burned. Adding

the .iso file as data will save the file to a medium, but it will not make the medium into a replica CD or DVD image.

After you have burned a complete set of CD/DVD media for a product from the downloaded ISOs, you can insert the "Installation Disk" (burned from the __00.iso image) in the computer's DVD drive to launch the installer. If AutoRun is enabled on your computer, the State of Indiana shield and the IndianaMap Framework Data logo will briefly appear in the center of your screen. An Indiana Ortho05 installation welcome screen will follow. If the installation window does not automatically appear, navigate to your CD drive and open the Startup.exe file:

1. Click the Install button
2. Read the product information text and click Continue.
3. Select the installation location you want and click Next. By default, the Indiana Ortho05 product directory structure will be built off the C:\root directory.
4. You can install the entire product dataset (all disks), or you can select a specific disk to install. If there is insufficient free disk space to install all selected data, the Install button will be grayed out and deactivated. To view information about the contents of a disk, hover the cursor over its line item to display a brief description. Click Install.
5. The installing dialog will display now, and you will be prompted to insert a series of disks. Click OK for each of these alerts. There is no need to insert new disks.
6. When the data installation process is complete, the word Done! will appear at the bottom of the status window. Click the Closes button to close the installation application. The State of Indiana shield will briefly display again.
7. To confirm successful installation of the Indiana Ortho05 product, navigate to the installation folder you selected (C:/ is the default). You will see an IndianaMap folder. The 2005 ortho imagery will be available in the Data folder. Metadata for the imagery is available in the Documentation folder.

The installation steps listed above apply to all of the data products delivered on CD/DVD media. More detailed information for each product can be found in the /documentation folder on the Installation disk (*product_name*__00.iso).

Credits - How You Should Cite the Data

Providing proper credit for the source of the IndianaMap data is important. It lets others know the data are part of the IndianaMap Framework Data program. Name recognition is an important step in generating and sustaining long-term support for maintaining these important statewide data sets.

The data is in the public domain and has no restrictions on distribution. Whether you use the data in whole or in part, credit should be listed as "IndianaMap Framework Data" with links to www.indianamap.org. You can credit the IndianaMap along side of your own and other partners' logos. The following IndianaMap logo can be used on maps and web sites with the data.

Let Us Know How You Are Using the IndianaMap Framework Data

We want to know about your successes! The Indiana Geographic Information Council is documenting how people are using the IndianaMap. This valuable information helps IGIC present a strong business case to decision-makers for maintaining Indiana's geographic information infrastructure. You can send us a few sentences about how you are using it to info@igic.org or http://www.in.gov/igic/contact_us/index.html.

2005 Statewide Orthophotography Help

We want to do everything in our power to ensure that all our partners, local governments, state agencies and other users can take full advantage of the 2005 Indiana Statewide Orthophotography products. In order to provide help as expeditiously as possible we have set up the following information for users:

- A half day data delivery/training seminar were held at key locations around the State. Participation included local government end-users with no-cost training to support immediate use of the products.

- Training will also be provided in Indianapolis at the IDHS to train County Emergency Management personnel to use their custom FirstView-First Responder application. This is a separate training from the above described training. Once again, participation is optional, but it will provide training to support immediate use of the application and data.

- As another option for help in using the 2005 Statewide Orthophotography you can contact

  Contact Information:

  Indiana Department of Homeland Security (IDHS)
  Roger Koelpin
  rkoelpin@dhs.in.gov
  317-232-0181

  or

  Indiana Geographic Information Council, Inc. (IGIC)
  www.igic.org
  info@igic.org
  317-234-2924

  For Technical Assistance with the installation disk, please contact:

  Phil Worrall
  Pinnacle Mapping Technologies, Inc.
  8021 Knue Road, Suite 113
  Indianapolis, In 46250
  Phone: 317.585.2011
  Fax: 317.585.2014
  pworrall@pinnaclemapping.com

  Data Acquisition by:

  Earthdata International
  45 West Watkins Mill Road
  Gaithersburg, MD 20878

  Data Quality Assurance and Distribution by:

  Dewberry & Davis LLC
  8401 Arlington Boulevard
  Fairfax, VA 22031-4666

Citations

The following books are useful for introductions to the basics of aerial photography.
American Society for Photogrammetry and Remote Sensing, American Congress on Surveying and Mapping and American Society of Civil Engineers, 1994. Glossary of the Mapping Sciences

> Everything you need to know about the mapping sciences from A to Z. The Glossary contains more than 11,000 definitions that encompass every aspect of the mapping sciences. Definitions are included in the areas of Photogrammetry, Remote Sensing, Cartography, Mapping, Land Surveying, Construction Surveying, Engineering Surveying, Geodesy, Hydrography, LIS/GIS/LIM, Surveying Law, and Metrology.

Avery, Thomas E. and Graydon L. Berlin, 1985. *Remote Sensing and Image Interpretation, 5th Edition,* Burgess Publishing Company.

> This book discusses the basics of aerial photography, and a wide range of uses for aerial photography from land-use mapping for GIS to soils mapping to studying urban development.

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> This book provides a good description of aerial photography and its use in city planning, although much of the technical information in the text is dated.

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> This book provides a good all around look at the current field of Remote Sensing, with focus on discussing methods of processing multi-band satellite imagery.

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> Dr. Mikhail and Dr. Bethel are both professors at Purdue University. In this edition, they team up with Dr. McGlone from Carnegie Melon University, to provide a mathematical look at the science of photogrammetry. They also take aim at a photogrammetric correlation of related fields, such as GIS and Remote Sensing.

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This book gives a full explanation and history to the science of photogrammetry. It discusses its many uses and advances in the field of study and gives a new focus to photogrammetric applications in GIS.